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Criteria for risk decision-making process related to hazardous installation : a French experience

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Abstract

Chemical process industry gathers critical infrastructures since chemical plants represent for the society both an instrument to generate activity and benefits (production of goods, employment, services...), and an instrument that can harm people and the environment.

This paper describes the risk assessment approach led in France for licensing the hazardous installation, in particular those covered by the Seveso II directive and the implication for land-use planning.

The first part explains why the French risk assessment procedure is based on the quantitative evaluation of major accident scenarios with explicit criteria, and only on qualitative analysis of the risk reduction measures without explicit criteria.

The second part shows some on-going evolutions in the formal definition of criteria to make the analysis of the safety barriers.

Keywords : decision-making, Seveso II Directive, land-use planning, risk assessment

Introduction

It can be considered that chemical process industry gathers critical infrastructures since chemical plant represents for the society both an instrument to generate activity and benefits (production of goods, employment, services...), and an instrument that can harm people and the environment.

Risk assessment and risk management are subjects of increasing importance in the chemical process industry throughout the Community. The Seveso II directive gives for the first time a requirement for the operator of hazardous industrial establishments to demonstrate "that adequate safety and reliability have been incorporated into the design, construction, operation and maintenance of any installation, storage facility, equipment and infrastructure connected with its operation which are linked to major-accident hazards inside the establishment". Hence, Seveso II explicitly encourages inclusion of risk assessment in the safety related decision-making processes of both regulatory authorities and industry.

For industry, it is important to better evaluate the risk in order to optimize the allocation of resources to prevent major accidents. In this respect, cost-benefit approaches have arisen in the industry, in particular in international industrial groups. So, in parallel to the evaluation of the cost of risk reducing measures, criteria have been developed to characterise the risk decrease.

For the regulatory authorities also, in order to insure a consistent process in risk management, it is fundamental to judge when they need to ask more risk reducing measures or when they are sufficient. Therefore, risk criteria are needed to appreciate if major accident hazards are well controlled by the operators.

This paper describes the risk assessment approach led in France for licensing hazardous installations, in particular those covered by the Seveso II directive and their implication for land-use planning.

The first part explains why the French risk assessment procedure is based on the quantitative evaluation of major accident scenarios with explicit criteria, and only on qualitative analysis of the risk reduction measures without explicit criteria.

The second part shows some on-going evolutions in the formal definition of criteria to make the analysis of the safety barriers.

1. Context in France

In France, there is no explicit criteria for risk acceptance of hazardous establishments. There are only general criteria related to the tolerable consequences of accidents, or regulatory texts that define safety distances around specific hazardous establishments.

1.1. Obligation to keep the population away from the hazards

In fact, in the law related to the control of hazardous establishments (Code de l'Environnement, Livre V), the license to operate can be subordinated to a sufficient distance between the establishment and people located around. In other words, the regulatory bodies can not license new establishments that can potentially harm people in case of a major accident.

This idea appeared first in a law dated 1917 on hazardous and insanitary plant, but it was clearly reinforced with the law n°76-633 dated 19/07/1976 that became the 'Code de l'Environnement' on 18th September 2000.

1.2. Development of the French deterministic approach for risk assessment

To enhance a harmonised implementation of the philosophy of the law presented above, the French Ministry of Environment published in 1990 a guide that defined reference scenarios to be considered for determination of safety distances for land-use planning. Then, in a circular letter published in 1992, it was explained that these safety distances should be determined using the safety reports written for the licensing procedure. Consequently, to write the safety reports that aim at characterising the hazard of their plants, the operators focused on the examination of the reference scenarios described in the guide. This approach is known as the French deterministic approach.

The term deterministic means that the assessed scenarios are pre-defined (See Table 1). They are considered independently of their likelihood, which is not assessed. The underlying philosophy is based on the idea that if sufficient measures exist to protect the population from the worst accident, sufficient protection will also be available for any less serious incident.

Table 1 : Reference scenarios used for land-use planning purposes

| Type of risks and facilities | Type of accident scenario |
|---|---|
| Risks linked to liquefied combustible gas facilities (fixed, semi-mobile or mobile) | Scenario A : . BLEVE (Boiling Liquid Expanding Vapor Explosion) Scenario B : . VCE (Vapour Cloud Explosion) |
| Risks linked to vessels containing liquified or non-liquified toxic gases where the containment is not designed to resist external damage or internal reactions of products | Scenario C : . Total instantaneous loss of containment |
| Risks linked to vessels containing toxic gases where the containment is designed to resist external damage or internal reactions of products | Scenario D : . Instantaneous rupture of the largest pipeline leading to the highest mass flow |
| Risks linked to large vessels containing flammable liquids | Scenario E : . Fire in the largest tank . Explosion of the gas phase for fixed roof tanks . Fireball and projection of burning product due to boil-over |
| Risks linked to use or storage of explosives | Scenario F : . Explosion of the largest mass of explosive present or explosion due to a reaction |

1.3. Criteria for the evaluation of the consequences of reference scenarios

In the safety report, the criteria used to characterise the hazard are expressed only in effect thresholds. They are used to evaluate the safety distances around the establishments :

- the distance at which the first death occurs corresponding to probability of 1% fatality,
- the distance at which irreversible health effects occur.

The effects that are calculated with mathematical models are different according to the physical phenomenon involved in the accidental scenario. And the effect thresholds correspond to the phenomenon. A list of the thresholds is given in Table 2.

It can be noticed that, in case of fragment projection after an explosion, the maximal distance is evaluated but it is often not taken into account for the determination of the safety distance.

Table 2 : Thresholds for the evaluation of the consequences of the reference scenarios

| Effects studied | Criteria corresponding to probability of fatality 1% | Criteria corresponding to first irreversible effects |
|-------------------|--|---|
| Thermal radiation | 5 kW/m ² (if the exposure is more than 1 min) or heat load of 1000 ^(*) (kW/m ²) ^{4/3} .s in case of a short exposure duration | 3 kW/m ² (if the exposure is more than 1 min) or heat load of 600 ^(*) (kW/m ²) ^{4/3} .s in case of a short exposure duration |
| Overpressure | 140 mbar | 50 mbar |
| Toxic dose | Based on LC1% and exposure time (passage of the cloud) | Based on irreversible effects (first injuries) and exposure time (passage of the cloud) |

^(*) : these values are commonly used, but still under discussion

It can be noticed that harmonised thresholds help to a coherent evaluation of the reference scenario consequences at a national level. Therefore, the French Ministry for Environment has published in 1998 a guide for the most frequently used toxic substances.

The guidance for the selection of the reference scenarios and the explicit definition of the criteria to evaluate the consequences is needed to have a consistent procedure, but at the moment we can still notice some discrepancies in the safety reports that have a great influence on the evaluation of the reference scenario consequences, in particular for toxic substances. For example, we can mention some parameters that should be more precisely defined in a guidance :

- The duration of the leak according to safety loop with quick-cut valves,
- The duration of the exposure for long leakage, regarding possible response time for people evacuation or confinement.

Moreover, as mentioned in the first results of the ASSURANCE project (F. Markert and al., 2001), not only in France, we can still notice some other discrepancies related to the models used for the consequence calculation and the assumptions made by the risk analyst.

1.4. Qualitative analysis of the safety barriers

The evaluation of the reference scenario consequences is often completed by the determination and evaluation of scenarios with preventive and mitigation devices. For this purpose, the process described in the Fig. 1 has been recently formalised, although it was already applied for some installations.

In the French safety reports, inspectors ask operators to identify the most important barriers (or lines of defences) that can prevent major accident scenarios. These specific barriers are called Safety Important Barriers SIB (in French : éléments importants pour la sécurité EIPS). The SIBs can prevent the occurrence of loss of containment of hazardous substances (preventive measures), or reduce the consequence severity of loss of containment (mitigative measures or response).

The SIBs can be constituted by safety devices (equipment) or by tasks carried out by personnel.

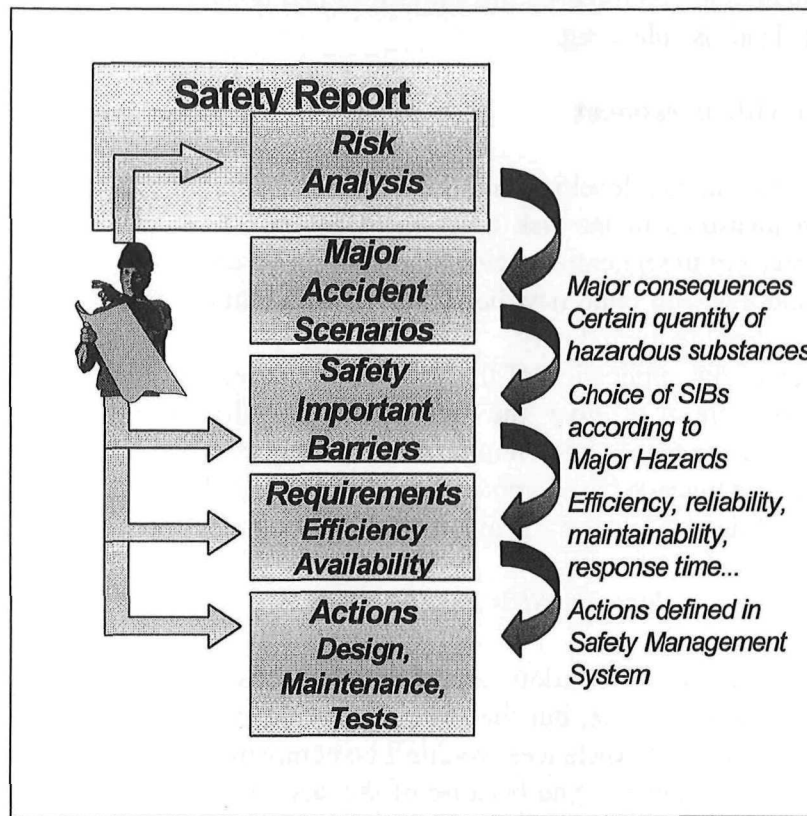


Figure 1 : Approach for determination of SIBs

The process to determine the SIBs is based on the following steps summarised in Figure 1 :

1. Risk analysis as part of the safety report, in order to identify and to rank the accident scenarios according to their severity and their frequency,
2. Identification of the Major Accident Scenarios according to the severity of the consequences, and on the criteria given in the SEVESO II directive (annex VI),
3. Association of each Major Accident Scenario with combinations of SIBs,
4. Definition of the SIB requirements in terms of efficiency and availability (depending on the reliability and maintainability),
5. Definition of actions, part of the Safety Management System (SMS), to insure the level of efficiency and of availability in the long term.

The SMS implemented by the operator aims at organising the process presented in Figure 1, and especially on the actions described in step 5.

As a partial conclusion, risk assessment for SEVESO II establishments is based, in France, first on a deterministic approach, with the evaluation of the reference scenario consequences (M.D. Christou & S. Porter, 1999). The approach applied since 10 years has led to implement concrete risk reduction measures, for example :

- Moving of LPG vessels away from urban areas,
- Covering of LPG vessels with earth or equivalent material,
- Confining of toxic gases vessels (chlorine, hydrogen chloride, phosgene...) and installation of a scrubber.

But it can be noticed that, often, only risk reduction measures that affect the severity of the potential consequences are required by the authorities and taken into account to define safety distances used for land-use planning.

2. New aspects in risk assessment

In the context of an industrial development, there is a need of criteria to quantify the influence of risk reduction measures in the risk assessment procedure, in particular if the measure affects the occurrence of the potential accident and not its severity.

It will allow to find a way to build new hazardous establishments, otherwise there will be no more possibility to develop the industry.

Moreover, because of the application of the SEVESO II Directive, the competent authorities have to accept or refuse to give the license periodically to operators of hazardous establishment, only if the risk is low enough. These thoughts show some of the limits of the deterministic and consequence based approaches, and express the need for explicit criteria to characterise the qualities (efficiency and availability) of the reduction measures.

2.1. Need for criteria to evaluate the SIBs and the SMS

In fact, the licensing of a new hazardous establishment needs that the evaluated scenarios are not always the reference scenario, but the scenario that takes account of some risk reducing measures, otherwise the safety distances wouldn't be compatible with existing urbanisation in the vicinity of the establishment. And because of the lack of explicit criteria, the number and quality of risk reducing measures (SIBs) are not always consistent when comparing the same kind of hazardous installation in different locations.

The requirements for the SIBs should be defined in terms of efficiency and availability in a harmonised way. And operators should evaluate if their safety barriers meet the requirements that should be proportional to the hazards. This assessment of the SIBs should constitute a first level of evaluation, and should be harmonised according to a methodology for instance based on the principle of the norms IEC61508 and draft IEC61511 (Functional safety : safety instrumented systems for the process sector).

The characteristics and the qualities of SIBs depend on the organisational process, as a safety equipment should be well designed, well kept up and tested. The organisation should also learn from the use of the equipment and build an appropriate maintenance planning. If the safety barrier is a human task, this task should be described in a procedure and the field operator should be trained to this procedure. The application of the procedure should be tested with audits.

Therefore, it is clear that the safety organisation, generally a Safety Management System, has a great influence on the qualities of the SIBs from the design phase to the decommissioning. Then it is recommended that the whole SMS should be evaluated by the operator itself or by an external auditor, as a second level of evaluation. In application of the SEVESO II directive, the inspectors check the existence of the SMS and its good functioning on particular points.

If the SIB characteristics meet the requirements associated to the severity of the potential major accident, then residual risk assessment scenarios could be defined by taking into account the SIB.

The consistency of the approach is summarised in Figure 2.

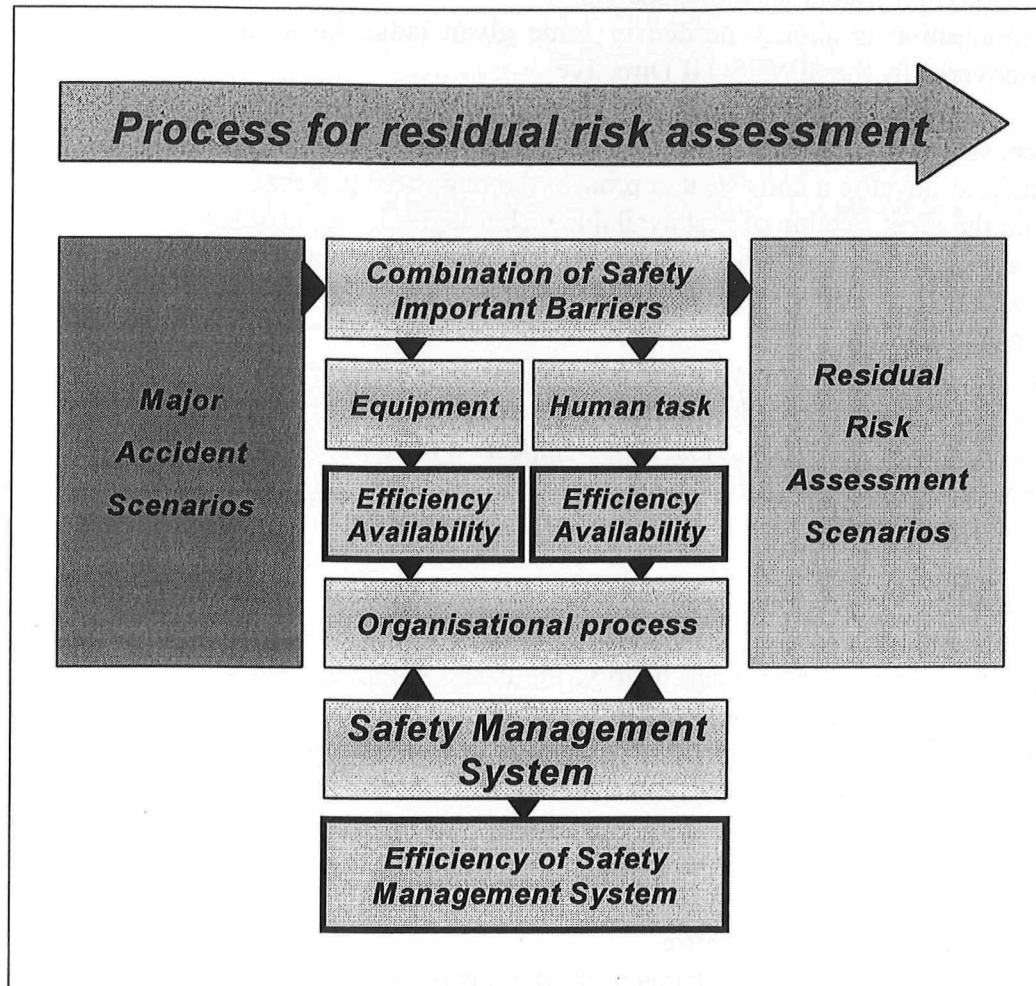


Figure 2 : Process for residual risk assessment

2.2. Pressure of the civil society for more transparency

A second aspect is that the public and the society ask for more transparency and the industrialists ask for more consistency from the regulatory bodies in applying the law at the national level, in the different regions. This observation is applicable in a lot of industrialised countries, not only in France.

But in France, it can be observed that the law is very complex and is applied by various stakeholders concerned by risk management, depending on the categories of the installation.

Therefore, there is a need to make the decision-making process more readable and explicit, in particular by implementing a methodology recognised by all the decision-makers in charge of risk control, and by adopting criteria to assess the efficiency of the risk reduction measures implemented by the operators.

2.3. Some thoughts to improve risk assessment and decision-making process

At the moment, in particular on the European level, we can notice a major initiative related to an harmonisation in risk assessment and decision-making process (C. Kirchsteiger and G. Cojazzi 2000) in different industrial sectors.

But harmonisation is already needed in some given industrial sectors, for instance in the industry covered by the SEVESO II Directive.

In France, some on-going projects at INERIS, supported by the French Environment Ministry, would help to develop a consistent approach. Among these projects, we can mention first, a project on the identification of best available technologies in terms of safety devices for given process equipment and substance, according to their efficiency and their availability. This project will help to better know the qualities of the safety devices able to insure the same safety functions.

There is also a working group on the revision of the guide for land-use planning. The first thoughts lead to keep a procedure to define the safety distances based on the evaluation of the consequences of accident scenarios. But, it appears a need for explicit criteria to characterise the acceptable residual risk for the people living in the vicinity of hazardous plants.

Conclusion

Because of the French culture and history, the decision-making process related to industrial accidental risk is based on the evaluation of the consequences of major accident scenarios. No explicit criteria are used to judge the acceptability of residual risk.

With the application of the SEVESO II directive and the change of the public's expectation in terms of transparency, the procedure for risk assessment should evolve. It could need the adoption of criteria to evaluate the efficiency of risk reducing measures implemented by the operators. These criteria should be proposed at the national level and endorsed by all the stakeholders involved in risk control.

If a similar evolution should happen in the decision-making process, in particular by proposing explicit criteria for residual risk acceptance, this would need a public debate in the society and some modifications in the law related to the control of hazardous establishments.

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